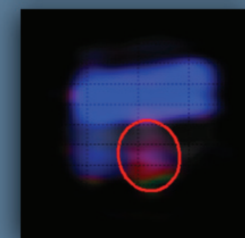
The widespread collaboration has led to new ideas on how to further put ultra-low-field MRI technology to use. Because the magnet doesn't need to be as large, the team envisions more portable (and less expensive) units, weighing just a few hundred pounds, that could be used by military medics for quick battlefield diagnostics or in hospitals in the developing world, hamstrung by the lack of funds and space for conventional MRI.

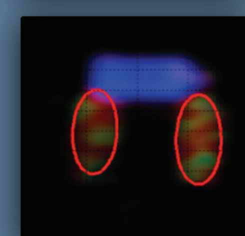
John Cannon is a science writer at Los Alamos National Laboratory.

Collaboration

MagViz development was led by the Applied Modern Physics Group from Physics Division along with collaboration from science and engineering divisions across the Laboratory including:

- Accelerator Operations and Technology
- Applied Engineering and Technology
- Hydrodynamic Experiments
- International, Space and Response
- Laboratory Directed Research and Development
- Materials Science and Technology
- Nuclear Nonproliferation
- Safeguard Science and Technology
- The National High Magnetic Field Laboratory





The sealed bottles above all look the same. Without time-consuming or potentially dangerous chemical tests, MagViz can tell the harmless from the harmful.

In the top image, a bin loaded with various commodities has a possible threat substance partially layered beneath a foil package. MagViz identifies the possible threat in the center container.

The lower image displays how MagViz can identify a possible hazard from otherwise normal and similar looking liquid containers.

In both images, the potential hazard is circled in red on the MagViz display.

HighlightPhysics

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From brains to baggage: a new take on MRI

By John C. Cannon

Thinking outside the box—or the magnetic resonance imaging (MRI) tube in this case—is nothing new at Los Alamos National Laboratory. So it's not surprising that an innovation originally intended to take pictures of the brain could enhance airport security, thanks to a team of Los Alamos researchers and their "MagViz" technology. About two years ago, an interdisciplinary team of Los Alamos researchers and students coaxed fuzzy brain images from a new, ultra-low-field MRI system. Instead of the powerful magnet used in traditional MRI, the Los Alamos device uses an ultra-low-field magnet similar in strength to the magnetic pull of the Earth—about 46 microteslas. By contrast, hospital MRI machines create a magnetic field 10,000 to 100,000 times Earth's magnetic field.

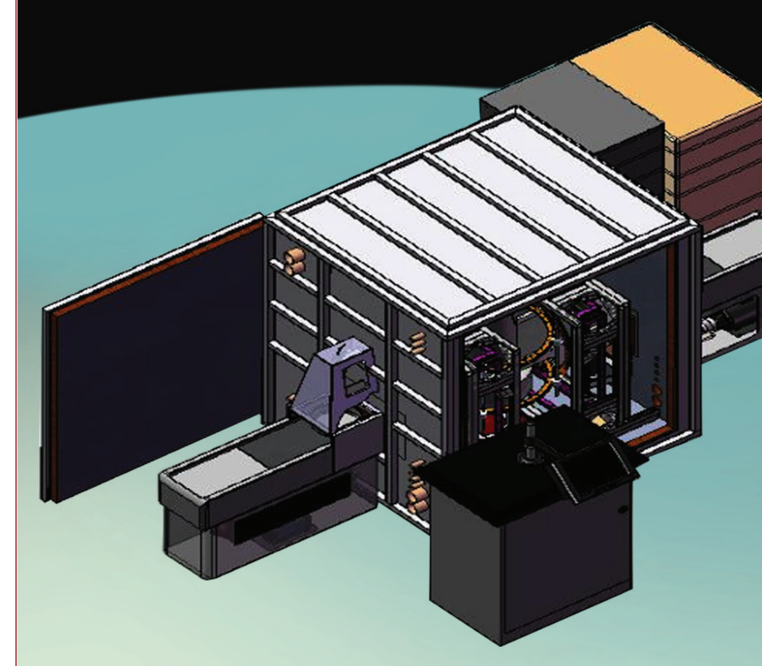
In the process of developing the brain scanner, then project-leader Bob Kraus and his team seized upon the idea that a versatile, low-field MRI might have applications beyond just medicine. The researchers hypothesized that they might be able to distinguish different liquids.

"Different parts of the brain are all very similar in their chemical makeup," said current Project Leader Michelle Espy, and yet the contrast allows doctors to differentiate aspects of the brain.

Starting with commonly available substances, the team found the system to be remarkably discriminating. "If we can tell the difference between V8 juice and Coca-Cola, which are mostly water," Kraus said, "why can't we tell the difference between shampoo and a threat substance?" Having liquids on airplanes has been an issue in air travel security since measures were implemented in 2006 to address the threat of terrorists using liquid explosives onboard aircraft. Today, the "3-1-1 rule," which requires that all carry-on liquids be kept in three-ounce bottles in a single one-quart, zip-top bag, remains a frustration to weary travelers.

In an MRI machine, magnetic fields cause hydrogen atoms to line up and spin in a substance—a bottle of water, a patient's brain, an injured knee—placed within its field. Kraus likens this to toy tops spinning on a table in synchronization with each other. Eventually, the tops begin to wobble, falling out of rhythm. This wobbling of hydrogen atoms occurs in unique patterns for different chemicals. And sensors in the MRI machine detect these

The MagViz MRI machine, soon to be tested at Albuquerque's international airport, can identify and assess the threat level of 50 different liquids.



Artist's conception of MagViz (Credit: Mark Taylor): The airport-bound MagViz machine should have a footprint about the size of x-ray screeners currently in use.

Screening agents operating MagViz will see a color-coded image with numbers to differentiate distinct containers. Green dots are benign substances. Red dots indicate threat substances, and if the machine cannot identify a particular liquid, the image will bear a yellow dot.

slightly different frequencies, which are in effect chemical fingerprints that can tip off technicians to the presence of distinct substances when translated to an image. In a hospital MRI, for example, the subtleties in the chemical composition of a tumor compared with that of healthy brain tissue result in a contrasting image.

Traditional hospital MRI machines depend on huge superconducting magnets that draw strong signals from scanned objects and provide clear resolution in the final images. The robust signal produced allows the diagnosis of everything from a torn knee ligament to a malignant brain tumor, but conventional MRI machines are not without constraints that would preclude their use in airports. Because of the strong magnet, any metal present muddies the signal and creates unusable images, so shuttling metal-containing suitcases, laptops, and metal containers through an MRI security line at the airport would be impossible.

A typical bin containing various liquid containers. Hazards are indicated by red dots while safe liquids are indicated in green.

The fainter signals that MagViz teases out with a weaker magnet challenged the Los Alamos team to make sense of the less-distinct images. To increase the strength of the signal, the team incorporated a prepolarization field 100 times stronger than the magnet used to measure the spin. The technology relies on sophisticated detectors called superconducting quantum interference devices, or SQUIDs. Whereas a hospital MRI detects spin with a sensor akin to a radio antenna, tuned to a specific set of frequencies, SQUIDs can pick up the oscillation of hydrogen or other atoms at any frequency.

Such sensitivity across the spectrum causes SQUIDs to receive both the desired signal and a lot of noise—unwanted information that doesn't pertain to the object of investigation. So the MagViz team has engineered new ways of filtering out the unwanted background noise, Kraus said. "The new generation of SQUIDs has an exquisite signal-to-noise ratio," he added. Another hurdle involved the superconductors in SQUIDs, which require supercooling with liquid helium down to 4 Kelvin, or about 269 degrees below zero Celsius. Although helium is available and routinely used in hospitals, the $20,000 helium-chilled cryostat is the most expensive component of the system. Kraus said the MagViz team is working on ways to recycle the helium and use it more efficiently.

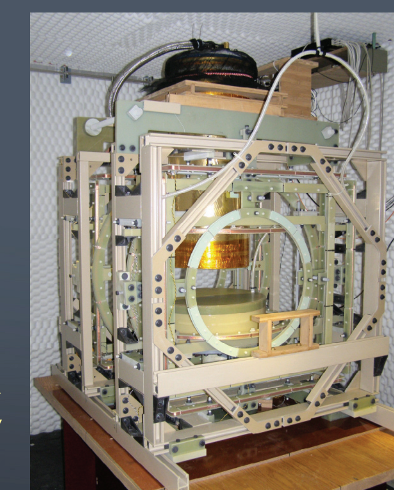
Challenges aside, MagViz boasts a host of benefits. Linked with a computer database, MagViz can now reliably identify some 50 liquids from their chemical fingerprints. And that's only the beginning. "That's one of the beauties of this technology," Espy said. "We can add different threats as we become aware of them."

If MagViz finds a chemical designated as a threat, the machine will mark the container with a red dot on the screen. Harmless substances get a green dot, and if the machine can't identify the liquid, a yellow dot appears, indicating that further inspection is needed. As new threats emerge, "we just put them in the database and set the gate," Espy said.

That "gate," she added, is a malleable security threshold that can be set very small, so that only the most benign substances get the green designation. Or, the tolerance can be relaxed to allow more liquids through and increase the speed of baggage screening. In its current incarnation, MagViz takes about a minute for the whole process, from applying the magnet to producing the image. The Homeland Security Advanced Research Project Agency (HSARPA) at the U.S. Department of Homeland Security Science and Technology Directorate, which is supporting this project with a $5 million grant, hopes the final version will be able to scan bags at a speed similar to the current security checkpoint x-ray machines.

HighlightPhysics

Although the MagViz system is capable of producing complex three-dimensional images, baggage-screening agents would see the straightforward color-coded readout that quickly gives them the information they need. Kraus hopes that MagViz will be helpful to security by reducing the chance that dangerous substances can make it onto airplanes, while simultaneously allowing passengers the convenience of traveling with liquids as they did before 2006. And the team is aiming for a system that allows travelers to leave everything in their bags, decreasing the time in security lines. Even now, MagViz can account for the weak magnetism that metals in suitcase frames exude, and can correctly identify liquids like soda inside metal cans—a feat that would stump a high-field MRI. A MagViz prototype is slated to be deployed for testing at Albuquerque's international airport in 2008. Espy said the machine will be about the size of a large x-ray baggage-screening machine.



MagViz prototype at Los Alamos National Laboratory

Microtesla MRI of the human brain combined with MEG
Journal of Magnetic Resonance **194** 115-120 (2008).

MagViz was developed from low-field MRI scanning technology that produced the first microtesla MRI image of the human brain

The MagViz team

The development of MagViz involved science and engineering divisions from across the Laboratory. Some members of the SQUID team (left to right in photo): Per Magnelind, Tuba Sahin-Owens, Henrik Sandin, John Gomez, Mark Flynn, Igor Savukov, Al Urbaitis, Michelle Espy, Mireya Balkireva, Jessica Hammon, David Jeffs, Karlene Maskaly, Pulak Nath, Jackie Gonzales, Vadim Zotev, and Andrei Matlashov.